The challenge of C-shaped canal systems: a comparative study of the self-adjusting file and ProTaper

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Abstract: INTRODUCTION: C-shaped canals are anatomic features that present the clinician with both diagnostic and operational challenges. The aim of this study was to compare the efficacy of the Self-Adjusting File (SAF; ReDent, Ra'anana, Israel) in shaping C-shaped canals with that of the rotary ProTaper file system (Dentsply-Maillefer, Ballaigues, Switzerland). METHODS: Sixteen mandibular second molars and 4 maxillary second molars with C-shaped canals were obtained, originating from native Chinese population. They were divided into 2 equal groups of 10 teeth each, based on similar canal morphology as presented in preliminary micro-computed tomography-derived images. One group was shaped using the SAF, whereas the other was shaped using the ProTaper file system. Reconstructed micro-computed tomographic images before and after treatment were superimposed over each other, and the percentage of the canal wall unaffected by the procedure was calculated. Comparison of the 2 groups for this parameter was performed using the Student t test. RESULTS: When treated with the SAF, 41% ± 14% of the canal walls remained unaffected by the procedure, whereas 66% ± 6% of the wall area was unaffected when using ProTaper, which was significantly higher than that of the SAF-treated group (P < .001). CONCLUSIONS: The SAF was more effective than the ProTaper file system in shaping the walls of C-shaped root canals.

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The Challenge of C-shaped Canal Systems: A Comparative Study of Self-Adjusting File (SAF) and ProTaper

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Key Words: C-shaped, root canal anatomy, ProTaper, Self Adjusting File, SAF

Running Title: SAF vs. ProTaper in C-shaped Canals

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Abstract

Introduction: C-shaped canals are anatomical features that present the clinician with both diagnostic and operational challenges. **Aim**: To compare the efficacy of the Self-Adjusting File (SAF) in shaping C-shaped canals with that of the rotary ProTaper file system. **Method**: Sixteen mandibular second molars and 4 maxillary second molars with C-shaped canals were obtained, originating from native Chinese population. They were divided into two equal groups of 10 teeth each, based on similar canal morphology as presented in preliminary micro-CT–derived images. One group was shaped using the Self-Adjusting File, while the other was shaped using the ProTaper file system. Reconstructed micro-CT images before and after treatment were superimposed over each other, and the percentage of the canal wall unaffected by the procedure was calculated. Comparison of the two groups for this parameter was performed using Student's t-test. **Results**: When treated with the SAF, 41.? ± 14.?% of the canal walls remained unaffected by the procedure, while 66.? ± 6.?% of the wall area was unaffected when using ProTaper, which was significantly higher than that of the SAF-treated group (*P* < 0.001). **Conclusions**: The Self-Adjusting File was more effective than the

ProTaper file system in shaping the walls of challenging C-shaped root canals.

Introduction

The C-shaped canal system is an anatomical variation mostly seen in mandibular second molars (1, 2). The main anatomical feature of C-shaped canals is the presence of a fin or web connecting the individual canals. The coronal orifice of these canals is usually located apically to the CEJ level and may appear as a single, ribbon-shaped opening with a 180° arc linking all the main canals (2,3) or a ribbon-shaped canal that includes the mesiobuccal and distal canals (4). Typically this configuration is found in second mandibular molars with fused roots, and its prevalence differs across races, with a prevalence as high as 52% in native Chinese populations (5). C-shaped canal anatomy has also been found in mandibular first premolars (6), mandibular first molars (7), third molars (8, 9), maxillary first molars (10) and maxillary second molars (11).

These C-shaped canals present a challenge to the clinician, both at the diagnostic and treatment level. These unique anatomical features are not easily recognized on a traditional two-dimensional periapical radiograph (12-14) (Figure 1); thus, the operator may first become aware of the anatomy of this root-canal system only when encountering the unfamiliar shape of the pulp chamber and its floor. With the increased use of CBCT for endodontic treatment planning, the clinician may be able to better detect and diagnose C-shaped canals prior to endodontic treatment (Figure 2).

Nevertheless, even when recognized as a C-shaped canal, cleaning, shaping and obturation of such a root-canal system present unique challenges to the clinician (15,16). These root-canal systems tends to have flat, wide-spreading fins, which may present an even greater challenge if mesh-like connections between the fins are present.

The rotary nickel-titanium files that are currently used are of great help when treating simple, curved canals with round cross-sections. However, these instruments are less effective when dealing with flat, oval canals (17,18). The assessment of the endodontic treatment may appear satisfactory when viewed on a periapical radiograph. Nevertheless, the extent to which the buccal and lingual recesses ("fins") or isthmuses were left unaffected by the endodontic procedure cannot be visualized. These un-treated parts of the root canal system may serve as a potential habitat or passage for bacteria (19).

While the distal root canals of normal mandibular molars are commonly perceived as being easy to clean and shape, a recent study indicates that this is far from true (20). ProTaper files, when used in long oval canals of the distal roots of normal mandibular molars following the manufacturer's instructions, have been found to leave up to 80% of the canal area unaffected by the procedure (20). Additional brushing motions with NiTi files (17) or circumferential filing with either stainless steel or NiTi instruments, which are commonly believed to address the flat anatomy of these canals, fail to make much difference; they still leave more than 50% of the canal wall unchanged (20, 21)

Canal cleaning and shaping may be further compromised when the flat fins of a C-shaped canal are present. In addition, although manual stainless steel K files may clean a higher percentage of the walls of C-shaped canals than ProTaper instruments, they do so with more procedural errors (22).

The Self-Adjusting File (SAF) System was recently introduced claiming to close the gap between what we believe we do and what we can actually achieve in long oval canals and their 3D reality (23,24). When SAF files were used in flat-oval canals of the distal roots of mandibular molars, similar to those used by Paqué et al (20), the extent of the unaffected canal walls was reduced to 23% (25). All of these studies suggest that the endodontic challenge of C-shaped canals may potentially be better addressed using the innovative approach of the Self-Adjusting File.

The present study was designed to test the hypothesis that the Self-Adjusting File may perform better than rotary files in the complicated anatomy of C-shaped canals affecting a larger percentage of the root-canal wall than is currently possible with rotary nickel-titanium files.

Materials and Methods

Teeth. Sixteen mandibular second molars and 4 maxillary second molars with fused roots were selected from a random collection of extracted teeth originating from a native Chinese population and subjected to micro-CT examination (see below). The inclusion criterion was the presence of a C-shaped root canal, as defined by Cooke and Cox (1). Only teeth with a C1, C2 or C3 configuration, as defined by Fan's modification of the original Melton classification, were included (2,26). Teeth with canals presenting C4 and C5 configurations, namely those with a single round or oval canal and those with no patent canal space, were excluded from the present study.

Experimental design. All teeth were scanned using a high-resolution micro-computed tomography system (μCT 40, Scanco Medical, Brüttisellen, Switzerland) with an isotropic resolution of 20 μm at 70 kV and 114 μA. After three-dimensional reconstruction, the teeth were initially paired based on eye-balled similar morphology. One tooth from each pair was randomly allocated to one of the two projected treatment groups, while the second was assigned to the other group. After the groups were formed, a flip of a coin was used to define which group would be treated with either the SAF or ProTaper procedure.

Two experienced endodontists served as operators, one experienced with the SAF procedure (MS) and the other experienced with the ProTaper procedure (LB). The operators had access to regular buccolingual radiographic images of the teeth but no access to the micro-CT 3D images of the teeth. Both used an operating microscope.

Cleaning and shaping: SAF. The access cavity was prepared, and the pulp-chamber floor was explored for its anatomy. The canals were negotiated with hand files (27) and working length was established at 1 mm short of the apical foramen, using buccolingual radiographs.

In cases in which a #20 K file could be freely inserted to working length with no advanced glide-path preparation, the Self-Adjusting File (SAF, ReDent, Ra'anana, Israel) was the first instrument to be used. In cases of narrow canals in which only #10 or #15 K files could be initially inserted to working length, PathFile instruments (013, 016, 019, Dentsply-Maillefer, Ballaigues, Switzerland) were first used to working length, followed by a #20 K file, to establish a free glide path to working length, as recently described by Solomonov (28).

The coronal orifice of the canal was funneled using an Sx ProTaper (Dentsply-Maillefer). The was then operated in the canal for 4 min, using a KaVo Gentle Power 20 LP handpiece (KaVo, Biberach, Germany) adapted with a vibrating RDT3 head (ReDent).

The micromotor rotation speed was set at 5000 rpm, which resulted in an in-and-out vibration at 5000 vibrations per min with an amplitude of 0.4 mm. Continuous irrigation was applied throughout the procedure at 5 mL/min using a VATEA peristaltic pump (ReDent) that was connected to the hollow SAF file via a silicone tube. For the first 3 min, 3% NaOCl was used for irrigation, followed by 1 min of irrigation with 17% EDTA. A final rinse with 5 mL 3% NaOCl was used to remove the EDTA, and the canal was dried using paper points.

Cleaning and shaping: ProTaper. The access cavity was prepared and the pulp-chamber floor explored for its anatomy. The canals were negotiated with hand files (27) and working length was determined with a #15 nickel titanium K-Files (Lexicon, Dentsply-Tulsa Dental, Tulsa, OK, USA) using buccolingual radiographs. The canals were instrumented with hand files using RC Prep (Premiere Dental, Plymouth Meeting, PA, U.S.A.), initiating with a #10 hand file, progressing with a #15 hand file and continuing until a #20 hand file could be negotiated to the working length, thus establishing a glide path.

The canals' coronal orifices were enlarged using ProTaper SX rotary files (Dentsply-Tulsa Dental), which were used with a brushing motion. All ProTaper files were operated at 300 rpm. All files were coated with RC Prep before insertion into the canal, and

all canals were irrigated after each file use with 2 mL of 3% sodium hypochlorite using a #25 size needle in a Luer Lock syringe.
The S1 rotary file was used next until the working length was reached, followed by the S2, F1 and F2 rotary files, using a brushing motion with the S1 and S2 files. The canals were then rinsed with 17% EDTA, rinsed with sodium hypochlorite and dried using paper points.

Micro-CT evaluation. Specimens were scanned initially and after root canal preparation at 70 kV and 114 µA with an isotropic resolution of 20 µm using a commercially available micro-computed tomography system (µCT 40, Scanco Medical).
A special mounting device ensured almost exact repositioning of the specimen in the scanning device; precision was further improved by reconstructing virtual root canal models based on µCT scans and superimposition of these models. Finally, precise repositioning of pre- and post-preparation images with a precision of better than 1 voxel was ensured by a combination of a custom-made mounting device and a software-controlled iterative superimposition algorithm (30).
The reconstructed and registered micro-CT images of the root canals before and after preparation allowed for visualization and

3D analysis of areas affected/unaffected by the procedure (20) (Figure 3-5). Matched images of the surface areas of the canals, before and after preparation, were examined to evaluate the amount of un-instrumented area. This parameter was expressed as a percentage of the number of static voxel surface of the total number of surface voxels. The software counts a surface voxel as belonging to any given structure when the full voxel belongs to it. Therefore, to be counted as ‘‘affected’’ at least one full voxel (i. e. 20μm) has to be registered as removed from the preoperative canal model after superimposition.

Statistical evaluation. The percentages of canal area unaffected by the procedure in the SAF and ProTaper groups were first checked for normal distribution using Shapiro-Wilk test, then compared using Student's *t*-test. All values were expressed as mean ± standard deviation.

Results

In the SAF-treated group, 41.? ± 14.?% of the canal wall was unaffected by the procedure, with a range of 21.?% to 70.?% (Figures 3 and 4). In the ProTaper group, a mean of 66.? ± 6.?% of the canal wall was unaffected by the procedure, with a range of

54.?% to 75.?% (Figures 3 and 5). This difference was significant at $P < 0.001$.

Discussion

The teeth used in the present study presented with a high variability of root-canal anatomy. At the same time, a limited number of teeth was available. Therefore, it was of great importance to verify that the difficulty level of the canals assigned to each group would be as similar as possible to those in the other group. Furthermore, to avoid any potential bias, the decision of which group would be treated by which method was postponed until after the selection of the teeth for the two groups. Then, the treatment to which each group will be subjected was determined by the flip of a coin.

The study was designed so that each of the operators was experienced with the method and the instruments applied; in the case of the SAF, which is a rather new device, this was especially essential. Each of the operators was instructed to accomplish the best treatment possible with the assigned instrument, however, neither had access to the 3D micro-CT images of the teeth; only buccolingual radiographs and an operating microscope were available. This limitation was imposed to reproduce clinical conditions as closely as possible. Nevertheless, the operators were aware that a C-shaped configuration is expected.

The anatomy of the root canals included in this study was highly challenging for both instruments, and neither of them performed at levels previously reported. Consequently, the percentage of the area unaffected by the procedure was higher than that reported for the same instruments in normal curved or long oval root canals (23,25,29), The reported level of the SAF performance with 25.8 ± 12.4% of unaffected wall area in curved canals and 23.5 ± 8.9% of unaffected area in flat canals could not be achieved in root canals with as difficult and unpredictable an anatomy as the C-shaped canals used in the current study. Therefore, it was not surprising that the SAF preparation left 41.? ± 14.?% of the canal wall unaffected by the procedure.

Nevertheless, given that the SAF was specially designed for operation in oval to flattened root canals, the results in the SAF group were significantly better than those in the ProTaper group, in which 66.? ± 6.?% of the canal wall was left unaffected by the procedure (Figures 3-5).

The level of performance in the ProTaper group in the present study required familiarity and experience with the ProTaper operating on C-shaped canals. It also required high competence in using this specific instrument, to achieve results such as those presented in Figure 3. It is doubtful whether a less experienced operator, such as a general practitioner working without a microscope, could perform at this level of proficiency by simply following the manufacturer's instructions.

The present study was limited to evaluating the hard tissue changes that occur during the procedures. It will be of interest to repeat such a study with a design aimed to investigate the irrigation efficacy in a similar setup; nevertheless, this issue was beyond the scope of the present study.

Paqué et al. have recently demonstrated that rotary files tend to pack dentin chips and debris into recesses adjacent to the files' central path of action, which could not be fully dislodged even with passive ultrasonic irrigation (30,31). It will be of great interest to conduct a similar study also in C-shaped canals to test for the extent of this recently described phenomenon in these recesses-rich root canals.

Conclusions

1. C-shaped canals presented a challenge to both file systems, which resulted in a percentage of canal area unaffected by the procedure that was higher than previously reported in normal canals.

2. The Self-Adjusting File was more effective than the ProTaper file system in shaping the walls of challenging C-shaped root canals.

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Legends to Figures

Figure 1. Mandibular and maxillary molars with C-shaped root-canal systems. Note the limited information available from the bucculingual radiograph alone.

Figure 2. A partial view of a CBCT radiograph presenting a C-shaped canal in a second mandibular molar.

Figure 3. The percentage of the canal wall unaffected by the procedure in C-shaped canals instrumented with either Self-Adjusting Files or ProTaper files. Each group consisted of 10 teeth. Differences between groups were statistical significant (Student's *t*-test, $P < 0.001$)

Figure 4. A C-shaped root canal treated with a Self-Adjusting File. A. Anatomy before treatment. B. Anatomy of the flat canal after treatment. Green represents areas unaffected by the procedure. C, D. Cross-sections at 4 and 6 mm from the apical foramen. Note the uniform removal of dentin all along the circumference of the long oval canal.

Figure 5. A C-shaped root canal treated with a ProTaper file. A. Anatomy before treatment. B. Anatomy after treatment. Green represents areas unaffected by the procedure. C, D. Cross-sections at 4 and 6 mm from the apical foramen. Note the circular shape of the file imposed on certain parts of the canal while not affecting the areas in between.

Note:

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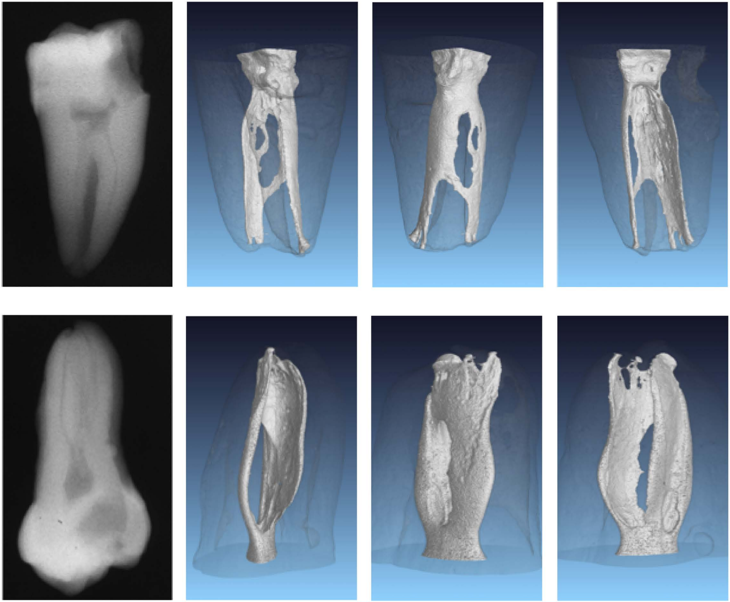

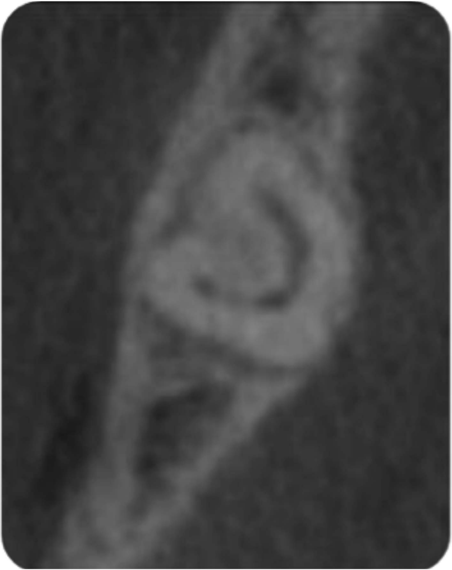

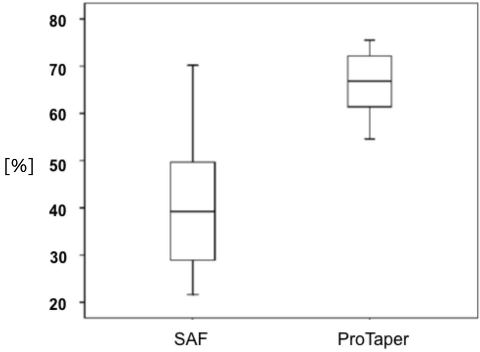

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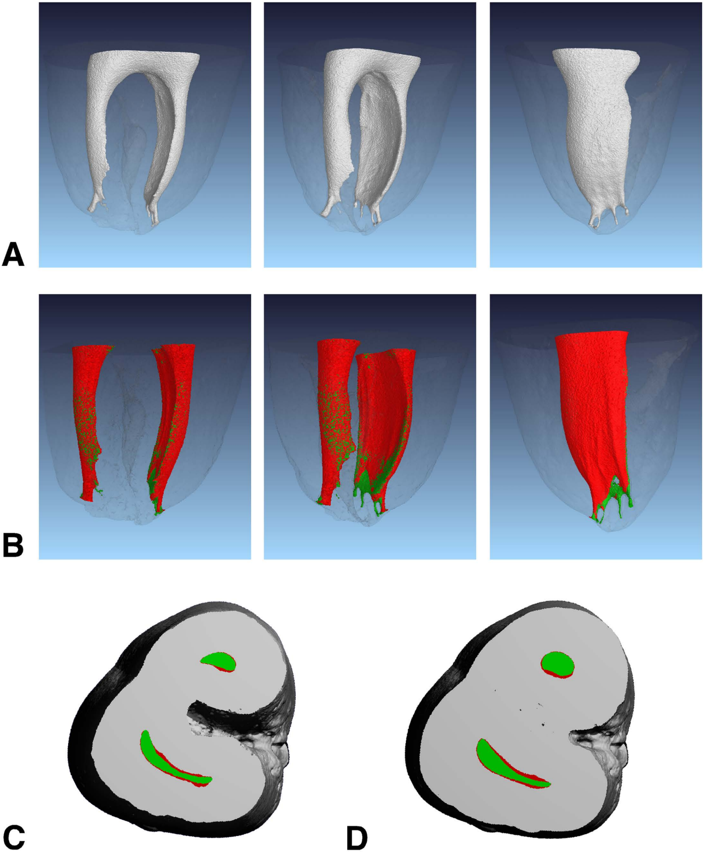
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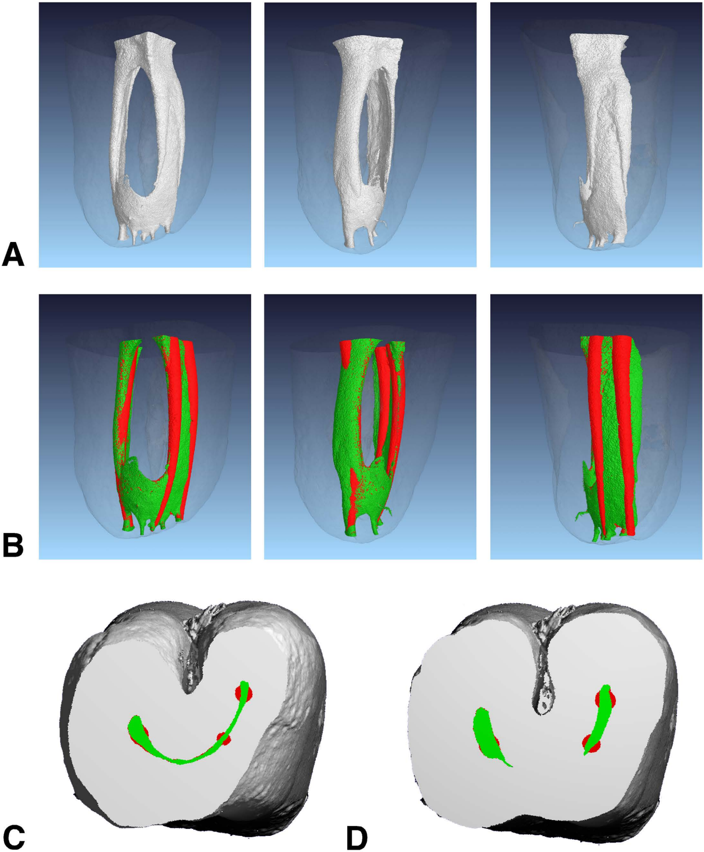
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